

A Briefcase Hardware Design for Data Acquisition Training

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iConnect Lab Training Enhancement Hardware Briefcase

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Abstract

This paper describes the collaboration between Michigan Technological University and A&D Technology Inc. to develop a hardware briefcase for training purposes with data acquisition and control software. A&D Technology currently provides in depth iTest software training for their customers. However, there is no related hardware training component. A&D Technology wishes to provide a more in depth training experience using relevant hardware. The hardware training component would present customers with real world scenarios that may occur when using the software. Therefore, faculty and students have designed a briefcase with discrete and modular I/O for hardware training purposes to be used in conjunction with the iTest software. The briefcase is mobile and can be brought to customer locations for training. The hardware briefcase communicates with the iConnect data acquisition hardware through a computer with corresponding software.

Components in the hardware briefcase include: Beckhoff Modular I/O, various discrete I/O such as push buttons, switches, and indicator LEDs. Another feature of this design is the incorporation of a stepper motor and timing belt system with a proximity sensor to detect rotations of the timing belt. The briefcase also includes a heater, fan, and thermocouple combination for analog data acquisition and control. The thermocouple data can be obtained from a thermocouple module as well as an analog input module. Thus, it allows conversion from a voltage signal to a corresponding temperature value.

A training manual is being developed, which will contain labs involving analog and discrete I/O, enabling a user to develop problem solving skills and further enhance experience with the iTest software. The training manual is designed to be a heavily engaging activity. The first lab is an introductory lab designed to familiarize the user with the iTest software and the hardware briefcase. As the labs progress, the user will have to use problem solving skills to become familiar with the iTest software and iConnect hardware. The last lab is a troubleshooting lab that simulates what a customer might face in industry.

Introduction

The primary purpose of this project is to provide a hardware training aspect to accompany the existing iTest software program. The reason for this is to train customers to better understand the interconnection between the iTest software and the iConnect hardware. The time frame for this project spans from fall semester of 2016 thru the spring semester of 2017. The fall semester was dedicated to design the briefcase and the spring semester is being utilized to build the briefcase and write the labs. The target audience of this project are operators, technicians, students and engineers who might utilize hardware and software from A&D Technology.

Similar products such as the Amatrol 990PAB53A Portable PLC Learning System is currently implemented at Michigan Technological University [1]. The case was chosen because of its ability to simulate real world applications and give the students the opportunity to see their programming operating physical equipment [1]. The case being designed by the authors aims to accomplish the similar goal as the Amatrol case but for a wider range of equipment and software.

The team is made up of four senior students pursuing a B.S. in *Electrical Engineering Technology*, two faculty advisors, and an industrial sponsor. All four students have taken courses in data acquisition and control. A&D Technology has a team of skilled engineers and technicians with many years of experience relevant to the project.

Goal

The primary goal of this project was to design and build a hardware briefcase that would be used in conjunction with the existing iTest software to provide in depth training of the software. This task is divided into several stages. First, the scope of training is determined and the corresponding equipment needed to accomplish it is located. Second, the optimal size of case is designed to be large enough to contain the required hardware, while small enough to be movable by a single person. Third, a layout of the equipment in the briefcase is developed in such a way that is ergonomic to the users and creates minimal interference with each other. Fourth, assembly drawings are created, followed by the electrical drawings and then parts ordering. At the present time, assembly of the briefcase is almost finished and the focus has shifted to the software aspect of the project.

Training Software Development

The iTest software being used for the project is a data acquisition and control software. The software platform is specialized in engine and chassis dynamometer, hybrid electric, battery component testing, transmission drive lines, hydraulic test systems, fuels & lubes, and durability applications. The software is used in a variety of industries with a prevalence in the auto industry. Currently, the A&D Technology offers comprehensive software training. The software training is typically two 8 hour sessions on site or via video conference training between the company and the customers. Beyond that, there is a help desk that the customer can call for software support. With this complex and versatile software, much of the training is left to be in the field, and come with experience. With the iConnect briefcase development, customers can have hands on experience with the hardware, enhancing the training experience. Prior to this project, there was no hardware training aspect for the control and data acquisition platform. The hardware briefcase project offers a portable hardware training solution.

Part of this project was to design a training manual with various labs to strengthen problem solving skills and enhance the training experience. Users who operate on the data acquisition and control software will have a chance to work with the hardware briefcase and complete 6 labs. The labs are in progressive sequence with a final lab allowing the user to utilize all the skills learned while working through the lab manual.

The first lab involves basic discrete I/O. The user will use the iTest software to turn LEDs on or off. The user will learn the basics of the iTest software and learn how to build displays and basic Human Machine Interface (HMI). The purpose of this is to familiarize the user with basic functions of the software, such as turning a digital bit on or off as well as assigning I/O to HMI pushbuttons via the software.

The second lab builds on the first lab and introduces users to the iTest programming syntax. The user will learn how to code if statements to assign a digital input to a digital output. The physical pushbuttons and toggle switches on the hardware briefcase will be used to control the LED lights. In this lab, the user will learn how to assign I/O channels in a way that controls an output. This allows the user to understand the programming language and how digital inputs and digital outputs work.

The third lab builds on these skills and then involves the usage of timers to simulate a stoplight. The user will learn how to set up a timing process in the software. A pushbutton will be pressed and a Green LED will be lit for 30 seconds, a yellow LED will be lit for 10 seconds, and lastly a red LED will be lit for 30 seconds. The stoplight timer can be reset at any time by pressing a pushbutton. The user can also flip a toggle switch to see the other side of the stop light to simulate perpendicular traffic. For example, if the light is green, the user can flip a toggle switch to see a red light which is what perpendicular traffic would see at a traffic light. This lab will give the user skills of creating timers in the software and learning how to latch outputs in order to create a controlled process.

The fourth lab involves the use of a stepper motor and encoder. The stepper motor will be controlled from the pushbuttons to start or stop it. The stepper motor and encoder are connected using a belt and two pulleys. The encoder receives feedback from the rotation of the belt. There will also be a proximity sensor to count the number of belt rotations. The purpose of this lab is to simulate a motor control. The stepper motor can be controlled by the iTest software.

Lastly, the final lab will involve a packaging and processing simulation process building on the knowledge and experience the user has gained in the previous four labs. The user will be using push buttons and switches to start up the simulated conveyor belt using the stepper motor. Once the conveyor belt reaches a number of rotations, an indicator LED will turn on and a timer will start within the iTest software. After a specified amount of time, the conveyor will run again. This process will be repeated using a pushbutton until a certain count is reached to simulate a product being packaged.

Hardware Briefcase Design

There are several criteria that needed to be met for the project, which had a direct effect on the case selection and design. The hardware briefcase needed to have a removable lid, the ability to install a panel, and it had to be easy to ship from location to location. The case the team ended up selecting is a Zero Manufacturing Guardian 1915 Case. The exterior dimensions of the case are approximately 17"W x 21"L x 9"H.

Some design aspects for the case are discrete and analog components. Our team wanted the case to be relevant to customer needs; so things like a PID controller, stepper motor and encoder, pushbuttons, LEDs, and toggle switches are included. A heater, fan, and thermocouple to simulate analog control is also included. The goal of the project is to include as many components as possible given the space constraints. Our team is very pleased with the relevancy of the components chosen for the design in respect of what the customers might encounter.

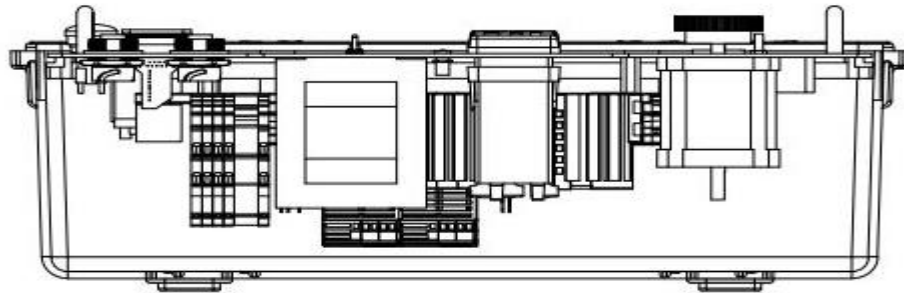


Figure 1 - Side wall through view of components inside case.

The major obstacle of the briefcase design that the team was able to tackle is if everything would fit into this relatively small case, given the amount of components going into it. Figure 1 is the side view through the case wall, which shows how close some of the components are and might be too large for this case.

Components

The modules for the trainer are all Beckhoff I/O modules. The reason is because A&D Technology uses Beckhoff modules almost exclusively. The Beckhoff modules chosen are the EK1100, ES3104, ES4134, ES5101, EL9011, ES1008, EL3318, EL2008, and ES7041 [2]. The EK1100 is needed to connect all of the EtherCAT terminals to the EtherCAT bus itself. The ES3104 is an analog input module; this is necessary to use thermocouples, fans, and a heater. The ES4134 is an analog output module that is needed to read the information coming from the thermocouple. The ES5101 is an incremental encoder interface, this is used to gather information about a stepper motor. The EL9011 is an end cap which is needed to complete the rail of modules. The ES1008 is a digital input terminal, this is used to gather the control signals and send them to the output module. The EL3318 is a thermocouple input with open circuit recognition capability which is used for the thermocouples that will not be controlled by the PID. The EL2008 is a digital output terminal that is used to send the information to the various discrete components. The ES7041 is a stepper motor terminal with an incremental encoder to drive the stepper motor.

The trainer has a stepper motor included [3]. There is a belt that goes from the stepper motor to a pulley that is connected to the encoder [4]. This allows information to be generated by the stepper motor. It will also simulate a conveyor belt since there will be a piece of metal attached to the belt and there will be an inductive sensor to tell when the piece of metal passes.

The PID chosen for the trainer is a 1/16 DIN Watlow PID [5]. This particular PID was chosen because its size and capabilities matched all requirements needed to work inside the trainer. The communication to the PID will be through Modbus RTU. Modbus RTU was chosen because A&D Technology uses RS232 in the industry and Modbus RTU can also be used over RS232. The PID controls a heater and a fan. This is added to simulate temperature control and to give the user some basic experience with a PID. The heater is a 24 V AC/DC 30W DIN Rail enclosure fan heater [6]. This heater was chosen because of its size and capabilities as the trainer case is not very large. Since the heater runs on AC, a transformer is used because the rest of the components in the case run on DC power [7]. The fan on the case is a 24VDC 60mm fan. This is used to make sure the case doesn't overheat and to simulate temperature control. Thermocouples will be used inside the case to monitor temperature and feed information to the PID [8].

The power supplies are 24 VDC, 4.2A power supplies [9]. These are chosen because 24VDC is a common voltage level found in industry. The power supplies are paired with a power entry connector so that the trainer case can be plugged into an outlet. There are also some solid state relays to help manage the current load inside the system. The trainer case will have various discrete components including: LEDs, an emergency stop, rocker switch, toggle switches and pushbuttons [10~13]. These components will be used to simulate basic functions, such as turning on a bit, pressing a start button, and turning on a bit with a switch. The emergency stop is there in case anything on the trainer gets out of control and the rocker switch will be used to power on the trainer. There will also be Ethernet and serial ports so that a computer can be directly connected to the trainer.

Design Process

The motor was a challenge that was actually pretty easy to overcome. The team knew they needed a 24VDC motor, which would be small enough to fit in the case, and would also be applicable to what was needed to accomplish for the project. The team found a 24VDC, 3Amp motor which would match up perfectly without having to change much with the project.

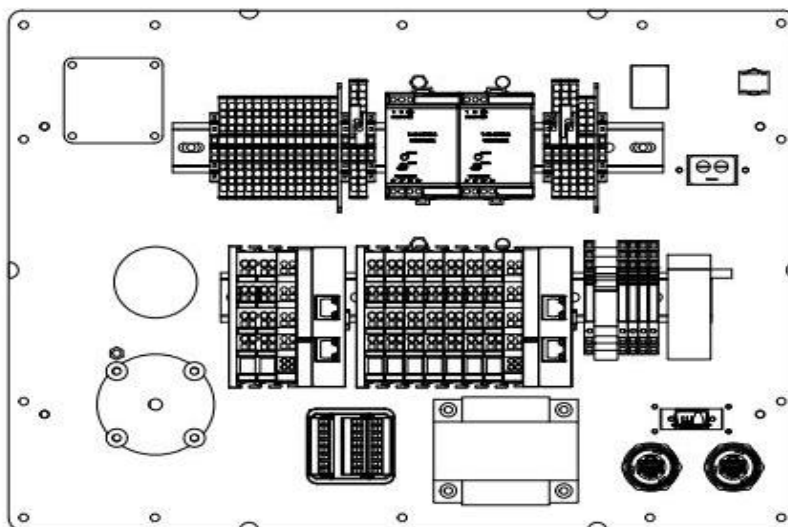


Figure 2 - Underside Panel View of Component Design

The biggest design challenge encountered was the task of fitting all of the components into the case while still making the case portable and ergonomic. The initial design the team came up with involved having the DIN rails mounted to the case, this was to be done by the case manufacturer. There were some complications implementing this design with the manufacture so the team had to design another plan. The next plan was to mount the DIN rails to panel, which would be offset and mounted with a threaded rod. This design was found to be less efficient than the final design, in which a 1" standoff was used to mount the DIN rails directly to the underside of the panel. This can be seen in figure 2. This was the most efficient and space conscious design possible for the project. Figure 3 shows the actual panel underside. Figure 4 shows the final edition of the panel edits, which is shown in a 3D model to give a sense of understanding with how everything is laid out and how most things will work. In Figure 5 one can see the actual hardware briefcase.

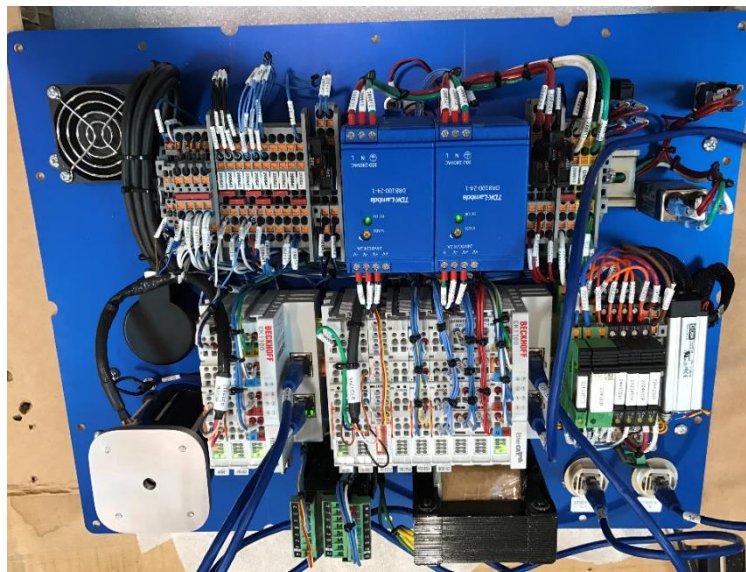


Figure 3 - Underside View of Panel as Built

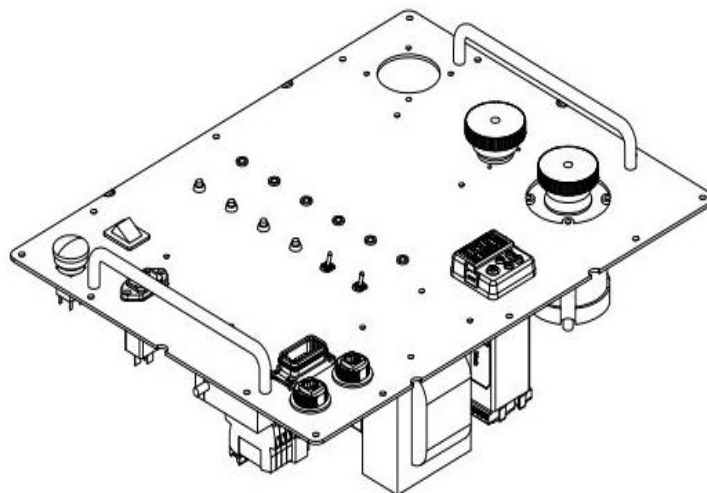


Figure 4 – 3D Angle View of Panel Design

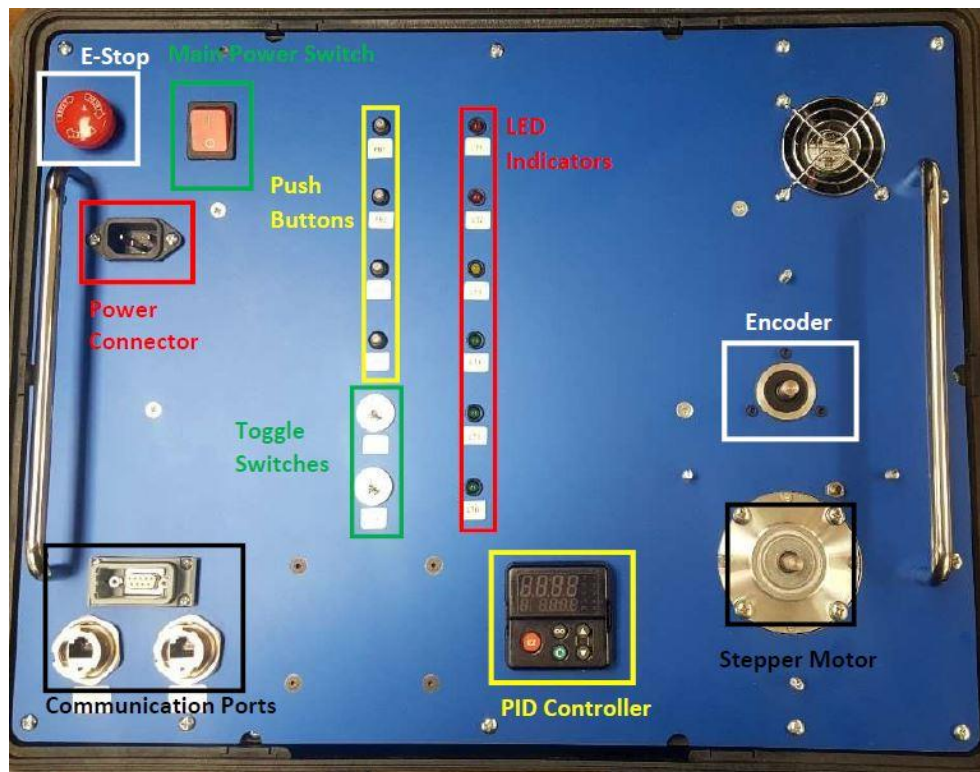


Figure 5 – Panel Design with Labelled Components

Conclusion

In conclusion, the team was paired with A&D Technology Inc. who had the need for a hardware component to augment the iTest training that is provided to their customers. The team has gone through with what A&D Technology wanted including Digital I/O, such as lights, switches, etc. The team also decided that analog components such as a stepper motor and a heater will help to broaden the training for the A&D Technology's customers. Beckhoff I/O modules are used to control the flow of information from the case into the computer to control the components via A&D's iTest software.

This project will also have many implications for Michigan Technological University, from publicity with A&D Technology, to provide a real world experience to engineers going out into the workforce. This A&D Technology has never paired with our university, and with a successful project it may help better connect the two in the future. The next benefit is that the students who are working on the project are getting real world experience in the engineering world before they graduate and work in the field. This gives the students an advantage in the workforce, and in job hunting, giving the university a better image of the students they produce. Above all else, this has been a wonderful real world engineering experience for the students.

This project also came with many design challenges which needed to be overcome. With the work of our team and help from A&D Technology, it has become a useful product that will

be used by the A&D Technology in the future for a hardware training aspect to the iTest software.

The team was also required to create a lab manual that will be used to aid A&D Technology in training of how to use the I/O box. These labs will range from using a switch to turn on an LED, to running many of the components in sequence to simulate a small process with the I/O box.

The design of this case will help many engineers who want to learn data acquisitions and controls. The case can be easily implemented with any other software or a PLC, making it a versatile learning tool. The case is also easily expandable in a modular configuration for additional components to control. These cases can be used in a business setting to train employees and customers, similar to the current design, or can be set up in a classroom for students. The case helps give visual examples of what the program can achieve, and creates an adaptive environment for debugging. It's much easier to tell what is happening when an LED doesn't light up when it's supposed to, rather than try and figure out what a certain error message means.

In the end, the team is very satisfied with this project. Not only because the design of this product can be used for many years by the A&D Technology, but also many life lessons are taught and real life industry experience is gained. The students learned a lot about teamwork, communication, design, etc. These skills will be very useful as the student's transition from school to industry.

References

- [1] A. Sergeyev, N. Alaraje and M. Azizi, Michigan Tech and Nucor Steel Partnership: State-of-the-Art Industrial Control and Automation Laboratory, 1st ed. American Society for Engineering Education, 2016, pp. 5-6.
- [2] "BECKHOFF new automation technology,". [Online]. Available: <https://www.beckhoff.com/>. Accessed: Feb. 8, 2017.
- [3] N. T. Corporation, "OD6025-24HSS," 1995. [Online]. Available: <http://www.digikey.com/products/en?keywords=P14315-ND%20>. Accessed: Feb. 8, 2017.
- [4] T.-N. 5000 -RZWD, "Incremental encoder (quadrature): 8mm solid shaft, 5000 PPR, 5-30 VDC," 1999. [Online]. Available: https://www.automationdirect.com/adc/Shopping/Catalog/Sensors_-z-_
- [5] "EZ-ZONE® PM express,". [Online]. Available: <http://www.watlow.com/products/Controllers/Integrated-Multi-Function-Controllers/EZ-ZONE-PM-Express>. Accessed: Feb. 8, 2017.
- [6] E. C. Control, "FGC0523.2R DIN rail enclosure fan heater 30W 24V ACDC," Enclosure Climate Control, 2017. [Online]. Available: <http://www.enclosureclimatecontrol.com/fgc0523-2r-din-rail-enclosure-fan-heater-30w-24v-acdc/>. Accessed: Feb. 8, 2017.
- [7] A. rights reserved, "Stancor - P-8664 - 4.19in.In 3.44in.In.W 50/60Hz lead Sec: 6A Sec: 24VCT Pri: 117V chassis transformer - allied electronics," 2017. [Online]. Available: <http://www.alliedelec.com/stancor-p-8664/70213383/>. Accessed: Feb. 8, 2017.
- [8] O. Automation and Safety, "E52-CA6DN 4M," 1995. [Online]. Available: <http://www.digikey.com/products/en?keywords=Z3792-ND%20>. Accessed: Feb. 8, 2017.
- [9] A. rights reserved, "TDK-Lambda - DPP100-24 - DPP series DIN rail Mnt enclosed 85-132/176-264V in 24V@4.2A AC-DC power supply - allied electronics," 2017. [Online]. Available: <http://www.alliedelec.com/tdk-lambda-dpp100-24/70177019/>. Accessed: Feb. 8, 2017.
- [10] A. rights reserved, "SloanLED - 252-242 - 0.5InH 0.06InT 6In Wire lead T 1-3/4 24VDC 5/16In Green LED indicator, Pnl-Mnt - allied electronics," 2017. [Online]. Available: <http://www.alliedelec.com/sloanled-252-242/70015917/>. Accessed: Feb. 8, 2017.
- [11] O. Automation and Safety, "A16Z-5070," 1995. [Online]. Available: <http://www.digikey.com/products/en?keywords=Z1428-ND%20>. Accessed: Feb. 8, 2017.
- [12] N. Switches, "100SP1T1B1M1QEH," 1995. [Online]. Available: <http://www.digikey.com/products/en?keywords=%20360-3289-ND%20>. Accessed: Feb. 8, 2017.
- [13] E-Switch, "LP10A1AB," 1995. [Online]. Available: <http://www.digikey.com/products/en?keywords=EG4643-ND%20>. Accessed: Feb. 8, 2017.